

**Changes in the distribution of *Acris crepitans blanchardi*, with
studies of nesting microhabitat and the possible impact of
ultraviolet-B radiation.**

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by
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CHANGES IN THE DISTRIBUTION OF *ACRIS CREPITANS BLANCHARDI*,
WITH STUDIES OF NESTING MICROHABITAT AND THE POSSIBLE IMPACT
OF ULTRAVIOLET-B RADIATION

An abstract of a Thesis by

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Field surveys were completed to determine the current distribution of *Acris crepitans blanchardi* (cricket frog) in Iowa, Minnesota, and South Dakota. These field surveys were unable to locate any populations of cricket frogs in Minnesota, South Dakota, or the northernmost tier of Iowa counties. This suggests that the range of the cricket frog has been reduced by approximately seventy miles from its northern extreme. The possible impact of ultraviolet (UV) radiation was tested on six species of amphibian eggs as a possible cause for this decline. These included *Acris crepitans*, *Ambystoma*, *Bufo americanus*, *Hyla versicolor* complex, *Pseudacris triseriata*, and *Rana pipiens*. The eggs were subjected to three different light treatments, allowing full transmittance of light, blocking out UV-B and lower wavelengths, and blocking out lower than UV-B wavelengths. *Acris crepitans*, *Ambystoma*, and *Rana pipiens* showed significantly greater susceptibility to these light treatments. Four factors contribute to radiation-linked destruction of cricket frog eggs. They are among the most susceptible to UV radiation. They are unprotected by large egg masses, egg sheaths, or pigment. They are laid closer to the water surface than other species studied. Finally, they are laid later in the year and are therefore exposed to a longer period of solar radiation than are the other frogs.

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INTRODUCTION

The ecological significance of amphibians is just becoming appreciated. Not only do adult amphibians consume large quantities of arthropods and other invertebrates, but they also serve as an important food source for many species of fish, birds, and mammals (Blaustein and Wake, 1990).

Some amphibians are referred to as indicator species. Certain amphibians are more susceptible to changes in the environment than other species. This is due in part because they inhabit both aquatic and terrestrial habitats; exposing them to both aquatic and terrestrial pollutants. Amphibians are particularly sensitive because of their highly permeable skin which can rapidly absorb toxic substances. In addition, the egg stage is extremely susceptible to chemical pollutants, and exposure to high concentrations of certain chemicals can result in developmental abnormalities (Duellman and Trueb, 1986).

Amphibian declines seem to be general with not all regions or all species in any one area affected. Possible causes include habitat destruction (Hedges, 1993), introduction of predators or competitors (Hayes and Jennings, 1986, Moyle, 1973), disease and parasites (Laurance, et al., 1996, Trennery, et al., 1994), pollution from pesticides (Kirk, 1988), acid precipitation (Harte and Hoffman, 1989, Beebee, et al., 1990) and increased levels of ultraviolet irradiation (Blaustein and Wake, 1990, Blaustein, et al., 1994)

In the upper Midwest, a species that appears to be declining in range is Blanchard's cricket frog, *Acris crepitans blanchardi* (Cricket frog) (Lanoo, 1994; Oldfield and Moriarty, 1994). In 1988, the cricket frog was listed as a species of special concern in Minnesota (Coffin and Pfannmuller, 1988). This classification was upgraded to state endangered species in 1996 (MNDNR, 1996). The northern portion of the cricket frog's historic range included the southeastern and

southwestern corners of Minnesota (Oldfield and Moriarty, 1994), the southern half of Wisconsin (Vogt, 1981), the southeast corner of South Dakota (Conant and Collins, 1991), and all of Iowa (Christiansen and Bailey, 1991).

Vogt (1981), as early as 1980, and Mossman and Hine (1985) observed declines in cricket frog populations in Wisconsin. Jung (1993) completed a census of Blanchard's cricket frogs in southwestern Wisconsin and found them at only 19 of 40 historic sites. Severe declines in cricket frogs have also been reported in Minnesota (Oldfield and Moriarty, 1994). Recent surveys of southeastern and southwestern Minnesota were unable to locate an existing population in Minnesota (Van Gorp and Van DeWalle, 1995; Van Gorp, 1996). Surveys in southeastern South Dakota have also been unable to locate existing populations (Van Gorp and Christiansen, 1997).

The decline of cricket frog populations in northwestern Iowa appears to be increasing. Christiansen and Mabry (1985) noted fewer Blanchard's cricket frogs in Iowa's Loess Hills than earlier studies had indicated. Lanoo (1994) studied the amphibian fauna of Dickinson County, Iowa, on the Minnesota border, comparing it with the study by Blanchard (1923) and concluded that cricket frogs had disappeared from the county. Collective analysis of these studies suggest that the species is progressively disappearing from north to south across the historic range in the upper midwest.

Cricket frogs are small, dark gray to brown frogs with a dark triangle between the eyes and often a rust or green colored middorsal stripe. Warts are also sometimes present. The frogs have a snout-vent length of 2 – 3.8 cm. They inhabit muddy shorelines of large and small streams with or without abundant emergent vegetation (Oldfield and Moriarty, 1994; Christiansen and Bailey, 1991; Vogt, 1981). In Iowa and Wisconsin they have been found along the shorelines of farm ponds (Christiansen and Bailey, 1991; Vogt, 1981).

Cricket frogs emerge from winter dormancy in late April. They typically breed from May into July. Cricket frogs are easily identified by the male's call, which is a *glick, glick, glick* sound similar to the clicking of ball bearings in accelerating succession. In Wisconsin, cricket frogs begin calling in late May and continue through July (Vogt, 1981). In northern Iowa, cricket frogs also begin calling in late May and continue until approximately the second week of August (J.L. Christiansen, Pers. Comm.). Oldfield and Moriarty (1994) report that cricket frogs are one of the last frogs to breed in Minnesota, calling from late May into July, along with green frogs (*Rana clamitans*) and bullfrogs (*Rana catesbeiana*).

Cricket frog tadpoles have a black tipped tail and reach a length of 3.5 cm. The tadpoles metamorphose five to ten weeks after hatching, usually in early August. Young frogs may stay active into late September, while adults become inactive in August (Johnson and Christiansen, 1976). Cricket frogs feed on tiny insects, eating enough to fill their stomachs three times a day (Johnson and Christiansen, 1976). They stay near water throughout the summer (Vogt, 1981), but will travel great distances in periods of drought (Fitch, 1958).

The objective of this study was to test the hypothesis that cricket frogs have declined from the northern extremes of their range in Iowa, Minnesota, and South Dakota. This was accomplished by resurveying the historic locations where cricket frogs had been found. In addition, this study will examine the hypothesis that nesting microhabitat may influence ultraviolet (UV) exposure and this may be one reason for the suggested decline. This will be accomplished by comparing nesting sites of anuran species found throughout northern Iowa. UV radiation impact on the eggs of selected anuran species found in northern Iowa, both those that appear to be in decline and those that remain abundant, were also studied.

Eggs from six species were studied with respect to egg microhabitat and the influence of UV radiation on survival. These include *Acris crepitans*, *Pseudacris triseriata*, *Hyla versicolor* complex, *Rana pipiens*, *Bufo americanus*, and *Ambystoma* (sp)(either *A. texanum* or *A. tigrinum*). Typical egg microhabitat are described below for each species.

Cricket frog eggs for this study were found in nests of five to fifteen. Egg masses observed were in standing water at depths of .5 – 2 cm, and most were attached to vegetation. These observations were generally consistent with the observations of Johnson (1992), Oldfield and Moriarty (1994), and Vogt (1981). Johnson (1992) states that female cricket frogs may lay up to 400 eggs on the surface singly or in groups up to seven and hatch in a few days. Oldfield and Moriarty (1994) state that female cricket frogs lay up to 200 eggs in groups of ten to fifteen. Vogt (1981) found clumps of cricket frog eggs attached to vegetation in flowing water.

Species of *Ambystoma* lay eggs in early spring. The species of *Ambystoma* was not identified and could have been either *A. tigrinum* or *A. texanum* based on the region where the eggs were collected. Their breeding season typically begins in late March or early April. They choose the shallow open areas of ponds and lakes as breeding sites. Each female may lay up to 1,000 eggs (Collins, 1982) in small clumps of 18 to 110 eggs (Vogt, 1981). Eggs are attached to vegetation near the pond bottom. The eggs typically hatch in a few weeks (Johnson, 1992). During this study, several small clumps of *Ambystoma* eggs were collected.

Bufo americanus (American toad) utilizes breeding sites including ponds, lakes, rivers, and swamps. The breeding season for the American toad begins in early May and continues through June. Toad eggs were collected on 18 May and 2 June. The American toad lays eggs in long strands of 4,000 to 20,000

eggs on the surface or near the surface of water (Collins, 1982). I observed egg strands of hundreds of eggs wrapped around vegetation and across the open water. The eggs were often entangled among vegetation, and Oldfield and Moriarty (1994) reported that they usually hatch in 2-8 days.

Hyla versicolor complex (gray treefrog complex) utilize woodland habitats, and breeding sites composed of marshes and bogs. The breeding season for the gray tree frog is from mid-May through June. In this study, gray treefrog eggs were collected on 19 June. Oldfield and Moriarty (1994) state that gray treefrogs lay up to 2,000 eggs singly or in small clusters. Johnson (1992) states that eggs are typically attached to floating vegetation in clumps of 30-40 eggs. Egg masses observed in this study were in clumps of 30-50 eggs. The eggs typically hatch in 4-5 days. Preferred breeding sites include fishless sloughs, woodland ponds, and swamps (Johnson, 1992).

The breeding season of *Pseudacris triseriata* (western chorus frog) may begin as early as late March, and continue into early May. The chorus frog requires a breeding habitat of temporary or permanent wetlands without fish populations, usually a grassland flooded by spring high water. Chorus frogs typically lay from 500–1,500 eggs in clutches of 20-300 (Johnson, 1992). The eggs are usually attached to submerged vegetation. Oldfield and Moriarty (1994) state that chorus frog eggs are laid in small groups of 5-20 attached to submerged vegetation. Egg masses were observed from 28 March until 19 April in masses of 5-10 eggs, and were found at depths of 2.5 – 11 cm below the surface. Chorus frog eggs were always found attached to vegetation or sticks below the surface. Hatching takes place from a few days to nearly a week after being laid, depending on water temperature (Johnson, 1992).

Rana pipiens (northern leopard frog) utilizes breeding habitats of ponds or lakes with meadows or open fields adjacent to the water. The breeding season

begins in late April and continues through May. The northern leopard frog lays up to 6,500 eggs in globular masses, often concentrated in one area. The northern leopard frog prefers breeding sites of marshes or shallow ponds with some areas of open water. The egg masses are attached to submerged sticks, cattails, or grasses. A single egg mass was collected in this study from Engeldinger Marsh on 19 April. The egg mass was found at a depth of 6.5 cm below the water surface and was separated into smaller clumps for the UV trials. Eggs usually hatch in 10-15 days, depending on water temperature.

MATERIALS AND METHODS

Field surveys were conducted from 20 May, 1995 to 20 July, 1997 in southeastern and southwestern Minnesota, southeastern South Dakota, and northern Iowa. The historic range of the cricket frog is comprised of locations that were identified before 1960 as having cricket frog populations. The twenty-two historic locations in Minnesota were obtained from the Minnesota Natural Heritage Database. The South Dakota Department of Game, Fish, and Parks provided thirteen historic locations in South Dakota. Specimen records used to compile the Iowa locations, both historic and present, were obtained from the following museums and research collections, listed in approximate order of number of specimens; Drake University Research Collection, Iowa State University, The University of Michigan Museum of Zoology, U.S. National Museum (Smithsonian), University of Kansas, Illinois Natural History Survey, University of Illinois Museum of Zoology, Field Museum of Zoology, Carnegie Museum, University of Nebraska, University of Minnesota, University of Wisconsin, Coe College, Luther College, Buena Vista College, Central College, University of Missouri, Kansas City, and the University of South Dakota. Additional sites were sought out by consulting with the Iowa Department of

Natural Resources and the Minnesota Department of Natural Resources staff, and also by locating sites while in the field that appeared to have suitable habitat for cricket frogs. All visited sites are described in Appendix I.

In addition to museum and research collection records of specimens collected after 1960, the present range of *Acris crepitans* in northern Iowa, Minnesota, and South Dakota was determined by conducting field surveys during the 1995 and 1996 field seasons. The field surveys were initiated approximately the first two weeks of May and continued through July each year. Visual surveys were completed at the sites during daylight hours to assess the habitat and also to search for active cricket frogs near the water's edge. Aural surveys were completed in the afternoon and evenings during conditions which were favorable for cricket frogs to call. Historic locations of cricket frog populations in northern Iowa and Minnesota were visited at least three times, and most historic locations in South Dakota were visited twice. Suitable habitats not known to support cricket frogs were also visited as time permitted. All anuran species heard calling at each location were noted. All locations visited in Iowa, Minnesota and South Dakota were mapped using a Geographic Information System.

Some historic localities were imprecise and were therefore unmappable and not used. Some localities were represented by many records while others were represented by a single specimen.

Voucher specimens from Minnesota were deposited in the Bell Museum of Natural History at the University of Minnesota, under special permit numbers 7508 and 7944. Voucher specimens from Iowa were deposited in the Drake University Research Collection under Scientific Collectors Permit 6494. There were no specimens collected from South Dakota.

Microhabitats of eggs were studied during spring and summer (1996 and 1997) for *Acris crepitans*, *Pseudacris triseriata*, *Hyla versicolor* complex, *Rana*

pipiens, and *Bufo americanus*. These species are all found throughout Iowa (Christiansen and Bailey, 1991). By comparing the location and conditions of microhabitats of eggs, it may be possible to suggest whether UV radiation could be a factor in the declining numbers and ranges of these amphibians. This is because eggs placed on the water's surface would be expected to receive more radiation than would eggs placed deeper. In addition, eggs typically laid in shaded areas would receive less radiation than those placed in sunlight. Microhabitat of the eggs and overall habitat were described using set parameters, including: depth of egg mass, egg attachment substrate, location of eggs relative to protecting vegetation, and egg mass structure. The depth of the egg mass was measured from the water surface to the top of the egg mass. Egg attachment substrate, relative location of eggs, and the structure of the egg mass are all descriptive of each egg mass. Attachment substrate was either none, living vegetation, or dead vegetation. To determine the percent exposure to the sun, the location of the eggs relative to protecting vegetation was determined by estimating the amount of overhead vegetation. Egg mass structure was a description of the egg mass.

Laboratory experiments were conducted to determine differences in sensitivity to UV radiation of amphibian eggs. Eggs were collected from *Acris crepitans*, *Pseudacris triseriata*, *Hyla versicolor* complex, *Rana pipiens*, *Bufo americanus*, and *Ambystoma* genus within 12 hours of oviposition. Eggs from each clutch were separated into three groups, and each was subjected to a different amount of UV-B radiation (290-320 nm) exposure. Different wavelengths of light were produced for each group by the use of, or absence of, filters. The three different groups were produced by covering the containers 1) with a Mylar filter to block out UV-B and wavelengths lower than 320 nm, 2) with a cellulose triacetate film (Kodacel) to allow UV-B transmittance but to block out

wavelengths lower than 290 nm, and 3) with no filter. Each set of eggs was housed in a 10 gallon aquarium with fluorescent lights on ten hours per 24 hour photoperiod. In addition, all eggs were subjected to a full spectrum of artificial lighting, a combination of Duratest Vitalife fluorescent lamps enriched in UV-A radiation, and Westinghouse FS-40 fluorescent sunlamps. The photoperiod for these experiments was six hours on and eighteen hours off. The eggs were allowed to develop for seven days. The transmitting properties of the Mylar and Kodacel were determined by use of a spectroradiometer. The Mylar blocked out 100% of UV-B (290-320nm), and the Kodacel allowed about 80% transmission of UV-B.

RESULTS

Distribution Studies

The historic range (prior to 1960) of the cricket frog in Iowa, Minnesota, and South Dakota as determined by analysis of museum records was mapped using a Geographic Information System (GIS), and is shown in Figure 1. Each point on the map represents a collection location for *Acris crepitans*. Some points represent only a single specimen, while others may represent multiple individuals collected.

The areas surveyed during the 1995 and 1996 seasons in Iowa, Minnesota, and South Dakota were also mapped with GIS and are shown in Figure 2. Figure 3 shows the location of all cricket frogs found in the 1995 and 1996 field seasons with all of the areas surveyed. The current range (1960-present) of the cricket frog in Iowa, Minnesota, and South Dakota as determined by analysis of museum records and field surveys, is shown in Figure 4.

No cricket frogs were found in Minnesota, South Dakota, or the northernmost tier of Iowa counties. Cricket frogs were found at one location each

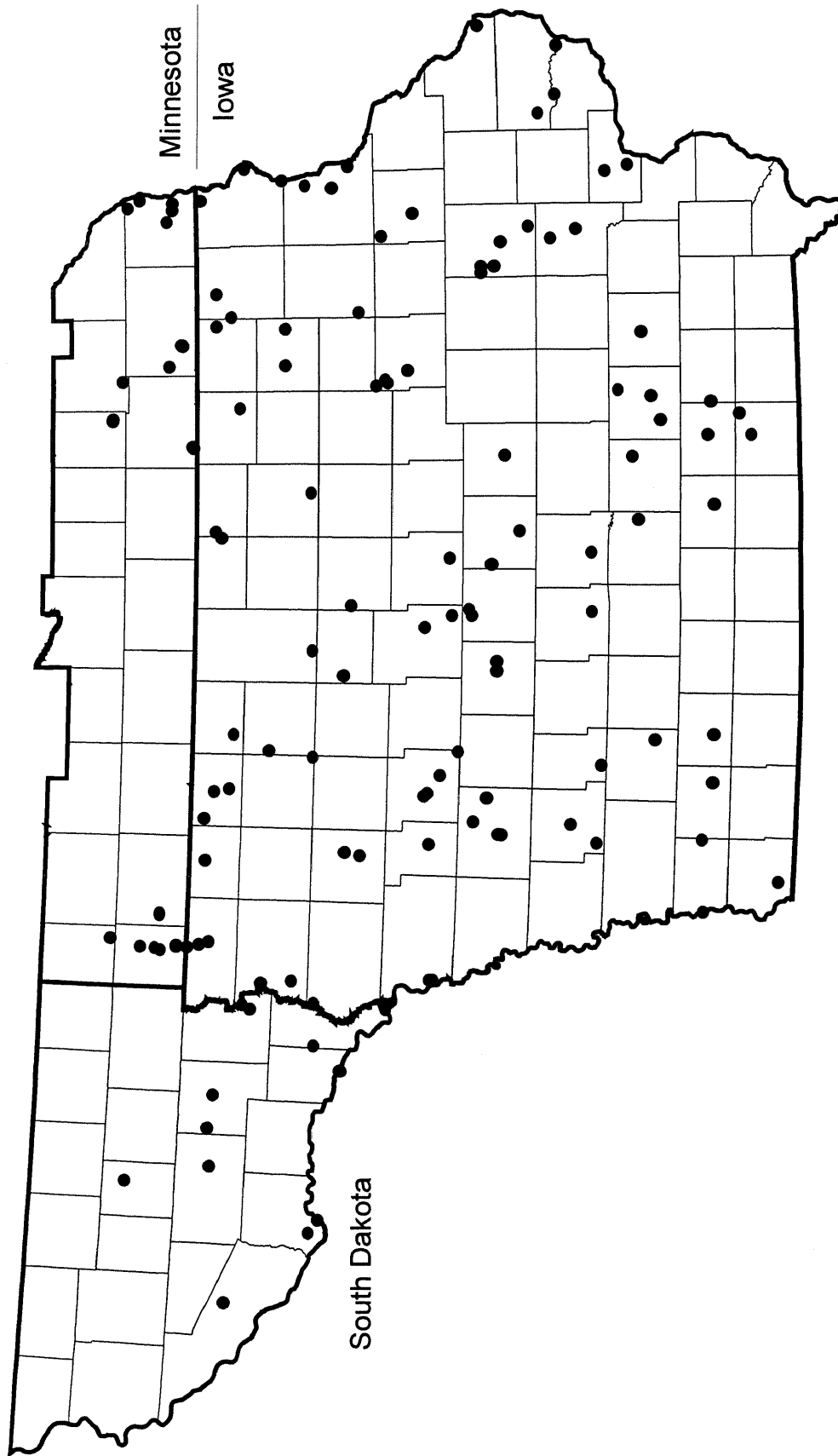


Figure 1. The historic (pre 1960) distribution of Blanchard's cricket frog in Iowa, Minnesota, and South Dakota.

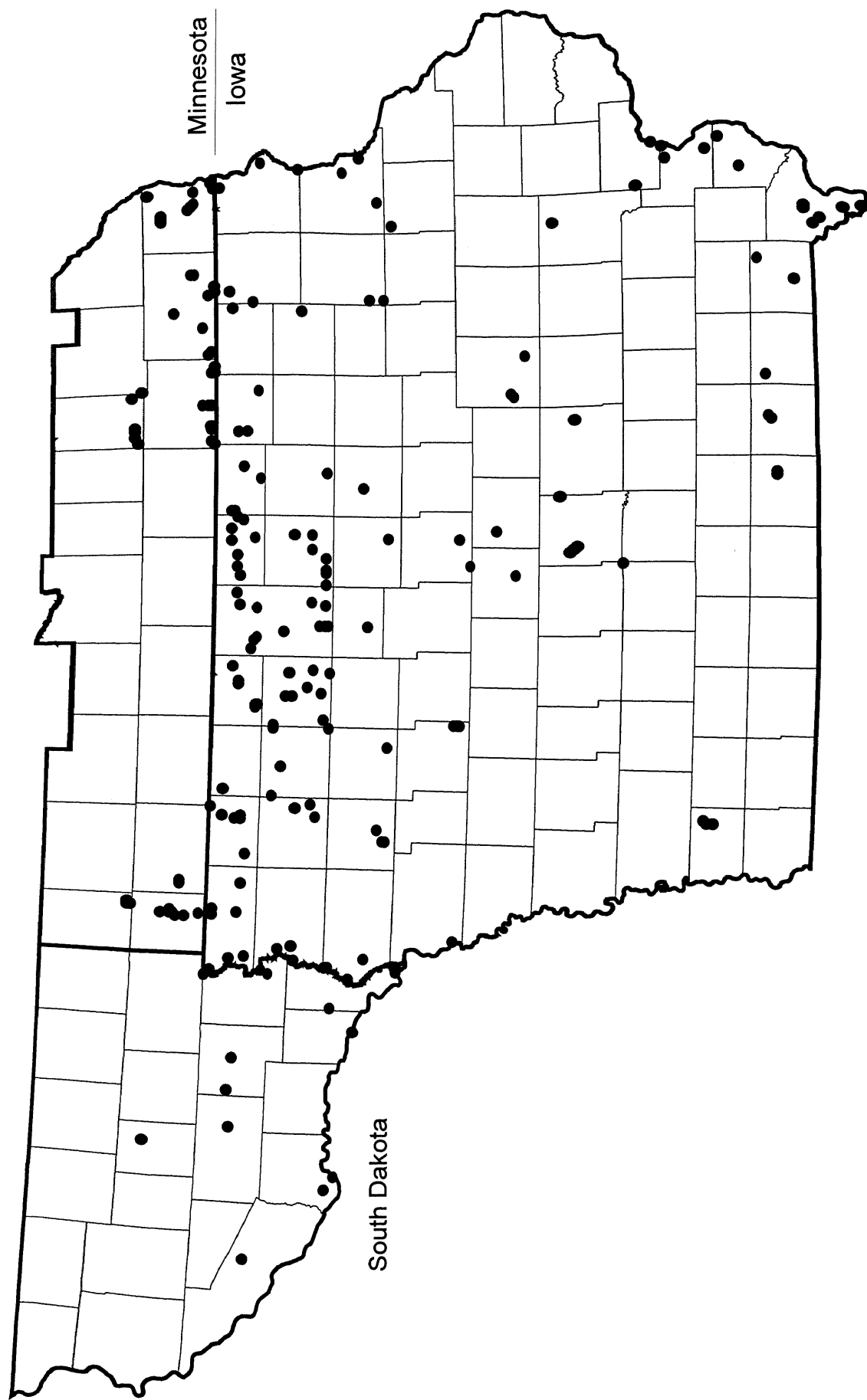


Figure 2. The locations of visits made in Iowa, Minnesota, and South Dakota during the 1995 and 1996 field seasons.

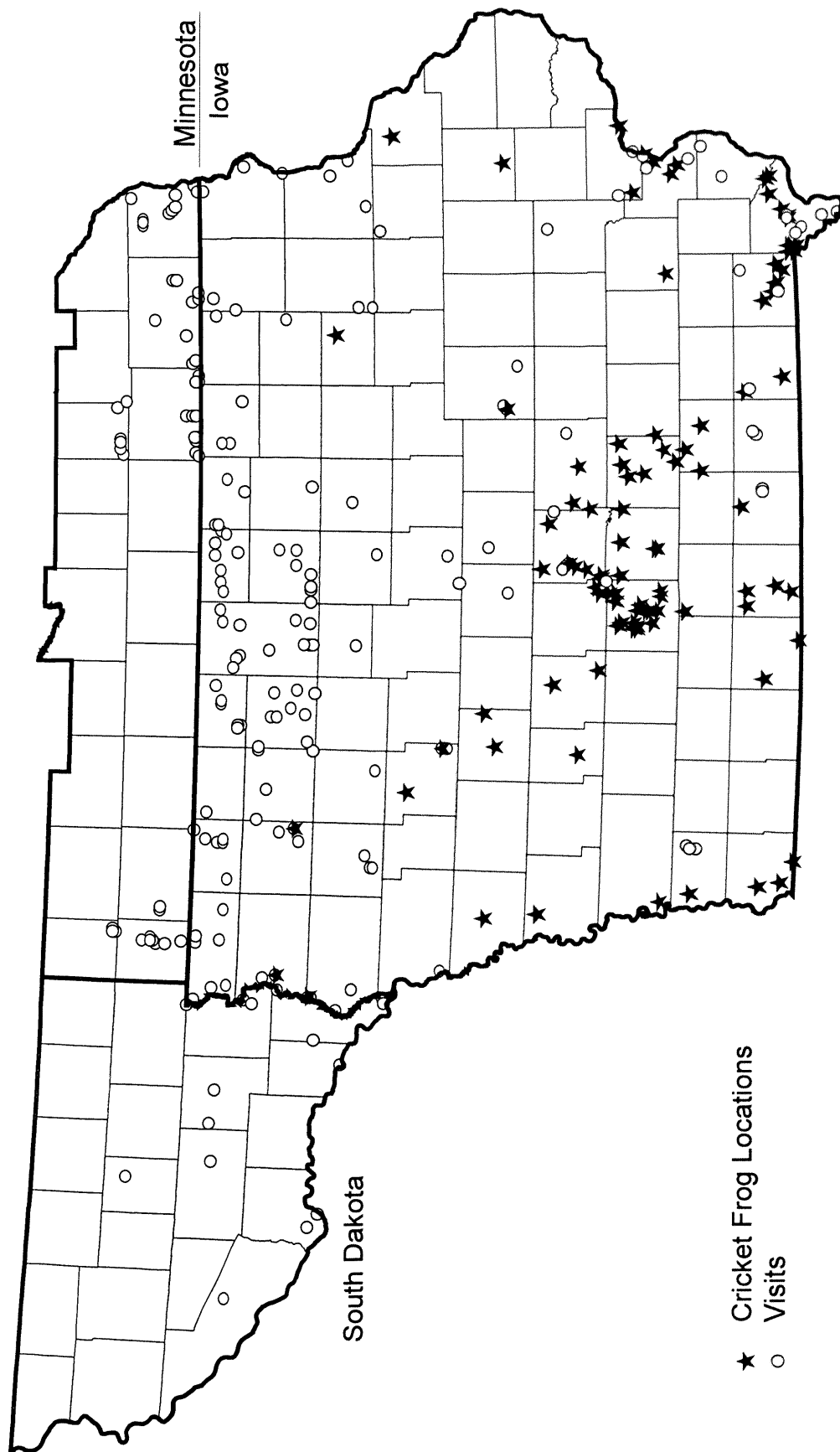


Figure 3. Visits made during the 1995 and 1996 field seasons and the current distribution of cricket frogs in Iowa, Minnesota, and South Dakota.

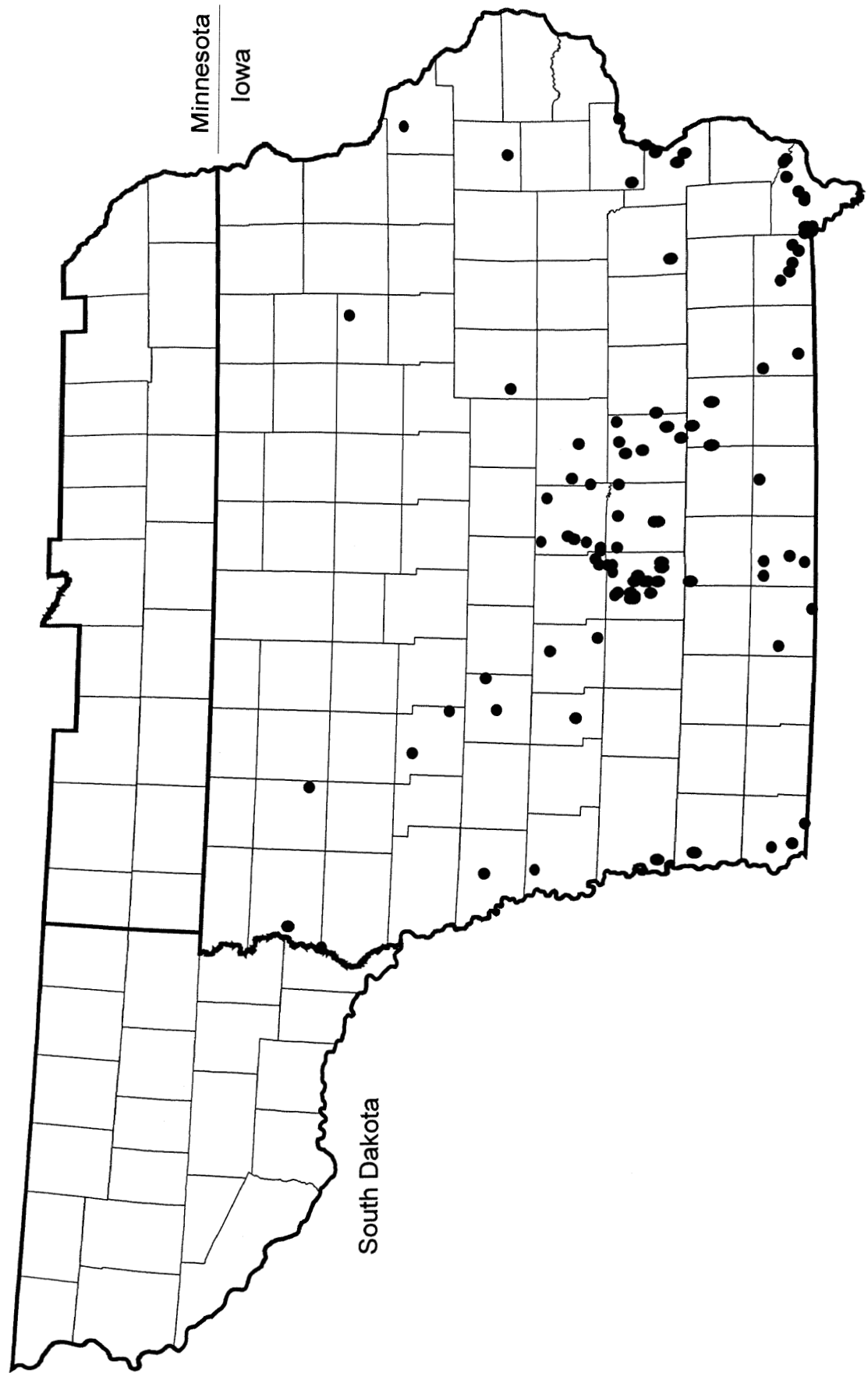


Figure 4. The locations of cricket frogs collected in Iowa, Minnesota, and South Dakota since 1960.

in Plymouth, Sioux, and O'Brien counties in northwest Iowa (Figure 4). These appear to represent the northernmost current locations for this species. These observations suggest that the range of the cricket frog has been reduced by approximately 70 miles from its northern extreme. Figure 5 shows the current and historic ranges of the cricket frog.

Egg Microhabitat

The egg deposition locations, percent sun exposure, and attachment substrate for nests of five species are shown in Table 1. The primary differences in location between species are the depth of the egg masses beneath the water surface and timing of ovaposition. *Pseudacris triseriata* laid eggs in depths from 2.5 cm to 11 cm, an average of 5.75 cm below the water surface. *Rana pipiens* laid eggs at a depth of 6.5 cm below the surface. *Hyla versicolor* complex laid eggs from 6.5 cm to 6.8 cm below the surface. *Acris crepitans* laid eggs in depths from .5 cm to 2 cm, an average of .75 cm below the water surface. *Acris crepitans* and *Hyla versicolor* complex were the latest to lay, being naturally subjected to the greatest UV exposure.

The percent exposure to sun and attachment substrate did not vary. All located eggs were estimated to be in >90% sun exposure. Nearly all eggs were laid on either living or dead vegetation. Partial strands of *Bufo americanus* eggs and one clutch of *Acris crepitans* eggs were laid in open water.

Laboratory UV-B tests yielded hatching success rates for the six species of amphibians. The average percent survival for each species, for each treatment, is shown in Table 2. Detailed results from individual trials are located in Appendix II. All species, except *Bufo americanus*, showed a decline in hatching success in response to the light treatments.

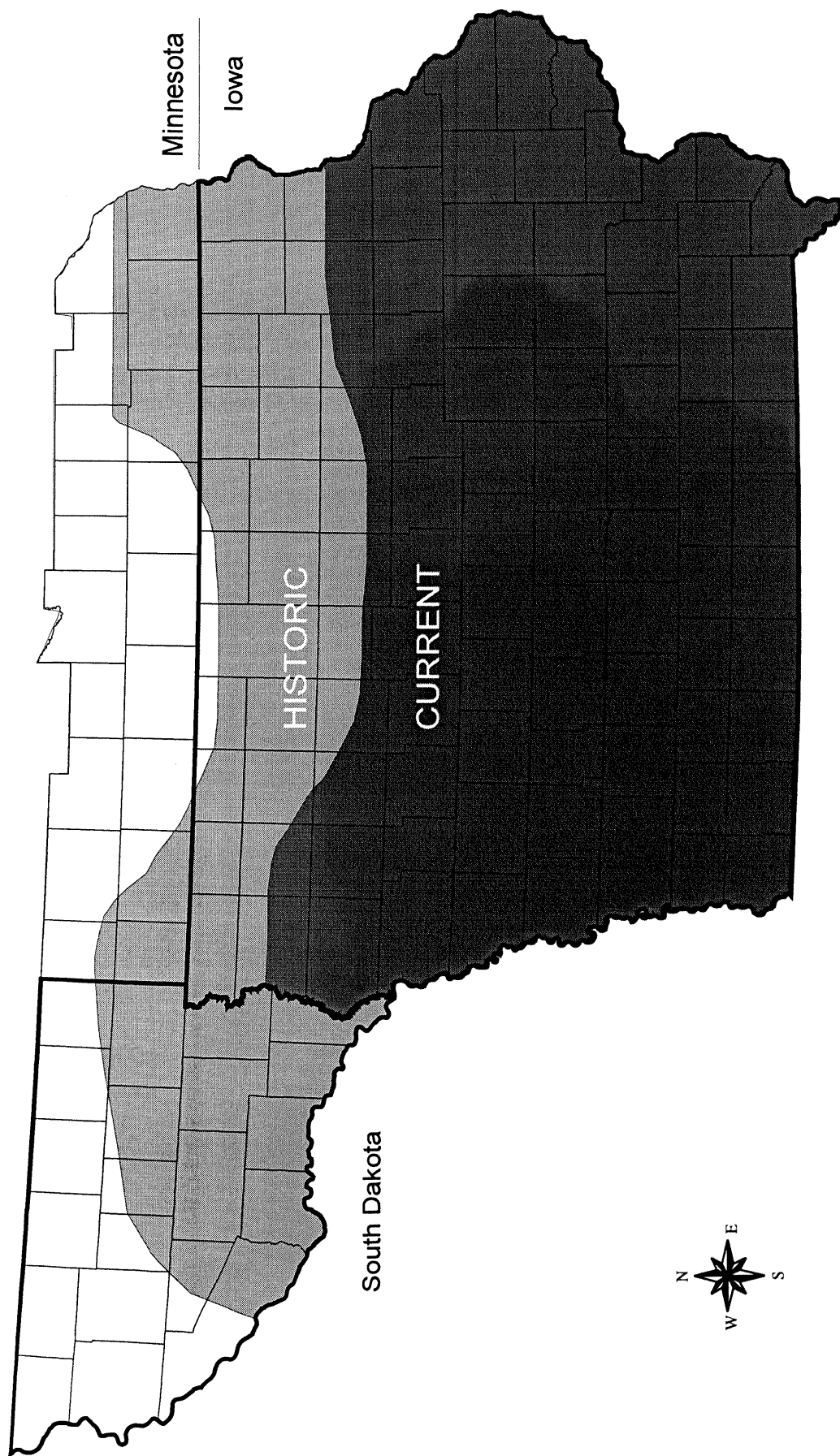


Figure 5. The current and historic distributions of cricket frogs collected in Iowa, Minnesota, and South Dakota.

Table 1. Egg mass size, depth below surface, percent sun exposure (lack of shade), and attachment substrate for five species of amphibians, and approximate day length.

Species	Number of eggs in mass	Depth below Surface (cm)	% Sun Exposure	Attachment Substrate	Mean Day Length
<i>A. crepitans</i>	5	.5	100	Yes	15 hrs.
<i>A. crepitans</i>	5	.5	100	Yes	15 hrs.
<i>A. crepitans</i>	13	.5	100	Yes	15 hrs.
<i>A. crepitans</i>	15	.5	100	Yes	15 hrs.
<i>A. crepitans</i>	15	.5	100	Yes	15 hrs.
<i>A. crepitans</i>	10	.5	100	Yes	15 hrs.
<i>A. crepitans</i>	10	.5	100	Yes	15 hrs.
<i>A. crepitans</i>	5	1	100	Yes	15 hrs.
<i>A. crepitans</i>	9	2	90	Yes, live plant	15 hrs.
<i>A. crepitans</i>	6	1	90	No	15 hrs.
<i>P. triseriata</i>	230	2.5	95	Yes, dead material	13 hrs.
<i>P. triseriata</i>	210	4.2	95	Yes, dead material	13 hrs.
<i>P. triseriata</i>	39	5.3	100	Yes, dead material	13 hrs.
<i>P. triseriata</i>	45	11	95	Yes, dead material	13 hrs.
<i>R. pipiens</i>	Thousands	6.5	100	Yes, dead material	13.7 hrs.
<i>H. versicolor</i>	220	6.5	100	Yes, live plant	15.1 hrs.
<i>H. versicolor</i>	210	6.8	100	Yes, live plant	15.1 hrs.
<i>B. americanus</i>	Hundreds	1	100	Some	15 hrs.
<i>B. americanus</i>	Hundreds	.5	100	Some	15 hrs.

Table 2. Mean percent survival of six species of amphibians, subjected to three different levels of UV radiation. Mylar blocked out 100% of UV-B, Kodacel allowed approximately 80% transmission of UV-B.

Species	Mylar (>320nm)	Kodacel (>290nm)	All light
<i>Acris crepitans</i>	87.96%	90.99%	14.29%
<i>Ambystoma</i>	96.97%	65.71%	11.76%
<i>Bufo americanus</i>	99.57%	92.41%	97.99%
<i>Hyla versicolor</i> complex	73.94%	69.78%	19.42%
<i>Pseudacris triseriata</i>	90.45%	84.27%	56.55%
<i>Rana pipiens</i>	83.43%	87.57%	86.20%

A One-Way Analysis of Variance (ANOVA) was run to determine if various light treatments significantly affected amphibian survival. The non-parametric Kruskal-Wallis ANOVA was run instead of the parametric ANOVA when the Bartlett's test of equal variances indicated the population variances were unequal. These results are shown in Table 3. The all light treatment was the only treatment that shows a significant effect at the .05 significance level.

The Tukey Honestly Significant Difference (HSD) test was run to determine if species survival was different by light treatment. These results are shown in Table 4. For the mylar and kodacel treatments, there were no significant differences in species survival between any of the species. In the all light treatment group, there were three groups in which the means are not significantly different from one another.

A One-Way ANOVA was also run for each individual species to determine if survival rates between treatments were significant using a .05 significance level. These results are shown in Table 5. *Acris crepitans*, *Ambystoma*, and *Rana pipiens* were significantly more susceptible to the light treatment than the other three species. *Hyla versicolor* complex and *Pseudacris triseriata* have marginally significant differences, and *Bufo americanus* does not show any significant difference between the treatments.

Table 3. Significance of treatment differences when applied to all species. $P=.05$

Treatment	Analysis of Variance P-value	
	One-Way	Kruskal Wallace
Mylar	0.4210	0.2725
Kodacel	0.2287	0.1735
All Light	0.0000	0.0000

Table 4. Tukey HSD comparison of means of survival by species.

Species	Mean Survival		
	Mylar	Kodacel	All light
<i>Acris crepitans</i>	0.9031	0.9487	0.1807*
<i>Ambystoma</i>	0.9808	0.6250	0.0741*
<i>Bufo americanus</i>	0.9958	0.9252	0.9737***
<i>Hyla versicolor</i> complex	0.7135	0.7288	0.1925*
<i>Pseudacris triseriata</i>	0.8783	0.8914	0.5485**
<i>Rana pipiens</i>	0.8561	0.8869	0.0831*

*Survival means with the same number of asteriks are not significantly different from each other. *A. crepitans*, *Ambystoma*, *P. triseriata*, and *R. pipiens* were significantly more susceptible to UV than were *B. americanus* and *H. versicolor* complex.

Table 5. One-Way ANOVA. Testing level of significance of difference between treatments. $P = .05$

Species	Analysis of Variance P-value
<i>Acris crepitans</i>	0.0001
<i>Ambystoma</i>	0.0029
<i>Bufo americanus</i>	0.5686
<i>Hyla versicolor</i> complex	0.0466
<i>Pseudacris triseriata</i>	0.0453
<i>Rana pipiens</i>	0.0001

DISCUSSION

Distribution Studies

The historic range of *Acris crepitans* extended north into the southern half of Wisconsin, southeast and southwest corners of Minnesota, southeast South Dakota, and across all of Iowa (Vogt, 1981; Oldfield and Moriarty, 1994; Conant and Collins, 1991; Christiansen and Bailey, 1991). This range appears to be declining from north to south. This was first noted in Wisconsin as early as 1981 (Vogt, 1981). This decline in Wisconsin was reaffirmed by Mossman and Hine (1985) and Jung (1993). Declines in cricket frog populations in Minnesota were reported by Whitford in 1990 and 1991, and also noted by Oldfield and Moriarty in 1994. These reports were reinforced with reports by Van Gorp and VanDeWalle (1995) and Van Gorp (1996). Declines in cricket frog populations were noted in northern Iowa by Christiansen and Mabry in 1985, and Lanoo et al. in 1994.

The cricket frog is adapted to living on muddy banks and shorelines of small streams, rivers, and ponds (Oldfield and Moriarty, 1994; Christiansen and Bailey, 1991; Vogt, 1981). During this survey, this type of habitat was found to still be present in the northern portion of the range. While much of the habitat had probably been altered since the original specimens were collected, it still appeared to be suitable cricket frog habitat.

Seventy-two locations were routinely surveyed for cricket frogs in Iowa, Minnesota, and South Dakota. Of these, sixty-five were historic locations. Cricket frogs were not found in South Dakota, Minnesota, or the northernmost tier of Iowa counties. There were cricket frogs found at one location each in Plymouth, Sioux, and O'Brien counties in northwest Iowa. The Plymouth and Sioux county locations are historic locations, and the O'Brien location is a new record.

Based on the results of these surveys, it cannot be concluded that cricket frogs are no longer found in these general regions. It can be determined with a high degree of certainty, that cricket frogs are no longer present at these historic locations. A comparison of the historic range with the current range (Figure 5) shows an approximate decline in the cricket frog range of seventy miles to the south. Future studies should continue within the historic range, but focus on areas with suitable habitat that have not been previously surveyed. Cricket frogs are known to wander great distances from water during both wet and dry weather (Fitch, 1958). Therefore, it is possible that small isolated populations may still exist in areas that were not surveyed far away from the historic sites.

Egg Microhabitat

To help determine the cause of the decrease in the cricket frog range to the north, egg microhabitats were studied, as well as egg susceptibility to ultraviolet radiation.

Within the Class Amphibia, some amphibians may be more sensitive to some factors than others. Certain species of amphibians may be more susceptible to ultraviolet radiation due to egg deposition locations, egg mass structure, and breeding season.

Egg deposition location, particularly depth below the water surface, may have a large effect on the developing eggs, including the effects of ultraviolet radiation on them. Eggs that are laid farther below the water surface may be more protected from UV radiation due to the rays being absorbed before they reach the egg mass. In this study, cricket frog eggs were found at an average depth of 0.75 cm below the water surface. Eggs from other species collected ranged from 5.75-6.7 cm below the surface. This may subject cricket frog eggs to higher levels of UV radiation than other species.

Cricket frogs lay their eggs in small clumps, exposing virtually all eggs of the clump to direct sunlight. Other amphibians that lay their eggs in a large clump, or in a protective sheath may not be as susceptible to the effects of the sun. Cricket frog eggs collected in this study were found in clumps of five to fifteen, while *Pseudacris triseriata* and *Hyla* (sp) laid eggs in clumps exceeding 200. The eggs collected from *Rana pipiens* were in clumps of thousands, and the *Bufo americanus* eggs numbered in the hundreds, but are in long strands in a protective sheath, not in clumps. Eggs laid in small clumps, such as the cricket frogs, do not provide as much protection to interior eggs as do larger clumps. The protective sheath on the *Bufo americanus* eggs may also provide some protection against ultraviolet radiation.

Cricket frogs breed and lay their eggs in late spring or early summer, when they may be exposed to higher levels of direct sunlight than early spring breeders are. The differences in breeding seasons subject each species to different environmental conditions. The positioning of the sun, the amount of daylight, and the air and water temperatures are all factors that change through the breeding seasons. These changes, in addition to other environmental stresses, may cause some species to be more vulnerable to conditions such as increased levels of ultraviolet radiation. The cricket frog is one of the last frogs to breed in this part of its range, calling from late May into July (Oldfield and Moriarty, 1994). Cricket frog eggs collected for this study were collected from 5 June to 1 July. One would therefore expect cricket frog eggs to have the greatest resistance to ultraviolet radiation, an expectation not supported by this study.

Increases in UV-B radiation reaching the earth's surface have been observed by Blumthaler and Ambach (1990) and Kerr and McElroy (1993). This

increase is due to the depletion of stratospheric ozone which normally blocks UV-B within the 290-320 nm range (Blumthaler and Ambach, 1990).

Acris crepitans, *Pseudacris triseriata*, *Hyla versicolor* complex, *Rana pipiens*, and *Ambystoma* showed statistically significant effects from the ultraviolet light treatments. *Bufo americanus* did not show a statistically significant effect due to ultraviolet radiation, therefore it was the most resistant species tested. The increased levels of ultraviolet radiation caused lower hatching rates and also caused some noted abnormalities, such as spinal abnormalities, in several species. Worrest and Kimeldorf (1976), Elinson and Pasceri (1989), and Blaustein et al. (1994) have demonstrated that UV radiation affects the embryonic development of some amphibians.

If the wavelength of light affecting the eggs was UV-B (290-320 nm), it is expected that the Mylar treatment would show greater hatch rates than the Kodacel or all light treatments. The ANOVA showed that there was no significant difference between the Mylar and Kodacel treatments. Both the Mylar and the Kodacel blocked out wavelengths below the 290 nm wavelength, and Mylar also blocked out wavelengths up to 320 nm. Mylar and Kodacel both allowed transmission of wavelengths above 320 nm. Therefore, it appears the UV-B wavelength (290-320 nm) does not affect the eggs, but rather a lower wavelength such as UV-C (100-280 nm). The UV-C range of light (100-280 nm) was totally blocked by both Mylar and Kodacel. UV-C is the highest energy ultraviolet light and is totally absorbed by the stratosphere, but may be produced by artificial light.

The Analysis of Variance (ANOVA) shows that there is a statistically significant difference between the all light treatment and the Mylar and Kodacel treatments, and no difference between the results of the Kodacel and Mylar treatments.

When the ANOVA was run on each individual species, three species showed significant differences between the three treatments. *Acris crepitans*, *Ambystoma*, and *Rana pipiens* all showed highly significantly reduced survival of eggs between the three treatments. *Hyla versicolor* complex and *Pseudacris triseriata* also show a significantly reduced survival, although not as strong. *Bufo americanus* was not significantly affected by the treatments.

Acris crepitans and to a lesser degree *Rana pipiens* may be expected to be more susceptible because they are late season breeders and are naturally subjected to higher amounts of sunlight. The cricket frog lays eggs in small clumps, which may subject more eggs to higher levels of sunlight. Leopard frog eggs are typically laid in a large mass of up to 5,000 eggs, many of which would be sheltered from the sunlight by the eggs on the outside of the mass. For this study, the mass was separated into smaller groups for each light treatment. Therefore, more eggs were exposed to the direct light than typically would be in a natural environment. This strongly suggests that the frog most susceptible to ultraviolet light is *Acris crepitans*.

There does appear to be differences in survival rates due to egg deposition locations and egg appearance. The cricket frog lays its eggs in small bundles attached to vegetation near the water surface. The small egg masses do not protect any interior eggs that may be protected by a larger egg masses. The large globular mass of eggs produced by leopard frogs has many interior eggs sheltered from harmful UV rays by the outer layer of eggs. The eggs produced by *Bufo americanus* are encapsulated in a sheath, which may provide additional protection against the harmful UV rays.

Pseudacris triseriata are early spring breeders that lay their eggs in small bundles attached to vegetation much deeper below the surface of the water. The *Hyla versicolor* complex also deposits their eggs farther below the water

surface than other species observed in this study. By depositing eggs deeper in the water, many of the sun's rays are absorbed.

In summary, a combination of the nesting characteristics of *Acris crepitans* and susceptibility of their eggs to UV light appear to contribute to the decline in the species distribution. The elements affecting survival appear to be the following: 1) In laboratory tests with all eggs approximately 1 cm below the water surface, *Acris* eggs were among the most severely affected by UV radiation, 2) In nature, *Acris* eggs are laid closer to the surface than those of any other frog species tested thereby subjecting them to more radiation exposure, 3) *Acris* eggs are laid without a protective sheath and in smaller clumps than most species tested, thereby giving even the deeper eggs less protection, 4) *Acris* eggs are laid later in the year than the other species studied, thereby subjecting them to the longest days and greatest radiation exposure.

Future studies on *Acris crepitans blanchardi* should continue to investigate the range and distribution throughout Iowa and the northern portion of the range. These field surveys should focus on areas near historic locations. All historic locations have been surveyed multiple times, and it appears the cricket frog has been extirpated from these sites.

Further studies to determine the effects of UV light should also quantify the amount of algae present in the waters that the eggs are laid in and also any pigmentation of the eggs. Both of these aspects could reduce the amount of UV radiation reaching the eggs. The different genetic dispositions between species may also determine how each species is affected by UV light. Further studies should also focus on conducting field experiments similar to those conducted in the laboratory. Eggs of multiple species should again be tested with different levels of UV light. This could be conducted in the field with mesh enclosures to keep the eggs in, and keep predators out. The top of the enclosure would be

covered with the different types of light treatments (Blaustein, et al., 1994). By keeping the eggs in their natural deposition locations, it may provide additional data not possible to obtain by bringing the eggs into the lab.

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APPENDIX I

Site Descriptions

Southeast Minnesota

Site 1. Two areas were checked along Otter Creek in Mower County. The Otter Creek locations were near bridges in sections 30 and 31, T101N, R17W. Both are historic sites from 1964 with habitat that still looks adequate for cricket frogs. The creek is slow moving and not very deep with some exposed muddy banks.

Site 2. The Little Cedar River site is in sections 28 and 33, T101N, R16W, Mower County. The Little Cedar is medium sized, and good habitat. The portion surveyed meanders through a pasture, with plenty of muddy banks, but not a lot of grassy cover. In addition, two shallow overflow areas adjacent to the river were sampled.

Site 3. The Upper Iowa River site is located at Lake Louise State Park in section 29, T101N, R14W, Mower County. The habitat is only moderately suitable due to the lack of muddy banks and the large amount of vegetation.

Site 4. The South Branch of the Root River was surveyed at the bridge where U.S. highway 63 crosses the river in sections 21 and 22, T102N, R13W, Fillmore County. This location is a historic locality (1939), with habitat only moderately suitable due to the lack of muddy banks and the large amount of vegetation.

Site 5. Canfield Creek, a historic location from 1941, was surveyed at two points in sections 10 and 11, T101N, R12W, Fillmore County. The majority of this creek runs through pasture land, with a small riparian area south of the bridge in section 10. Habitat overall appears suitable.

Site 6. Crooked Creek, a historic location from 1981, in section 16, T102N, R5W, Houston County is a small stream with steep rocky banks. The habitat at the site appears moderately suitable for cricket frogs.

Site 7. Crooked Creek at Freeburg in section 30, T102N, R4W, Houston County is a historic site from 1953. The habitat still appears to be suitable. This section of the creek has more rock along the banks than other portions, but the banks are still partially muddy.

Site 8. Crooked Creek in section 28, T102N, R4W, Houston County. Whitford (1991) reports, "positive ID of 3-4 calling Blanchard's cricket frogs" from this location, but no voucher specimens were collected. The habitat appears suitable, with muddy banks and quite a bit of ground cover. A small wetland is located approximately 100 yards north of the bridge.

Site 9. The Root River north of Hokah, a historic location from 1949, is in section 32, T104N, R4W, Houston County. The site appears suitable for cricket frogs, with some muddy banks and slower flowing areas.

Site 10. The site is located north of the Root River at Hokah in sections 29 and 32, T104N, R4W, Houston County. A large, shallow pool with an extensive mudflat is found at the site. It would be considered ideal habitat for cricket frogs except for the possibility that it regularly dries up. During the survey period, a noticeable drop in the water level was observed.

Site 11. The site is located at the bridge where Hwy. 6 crosses Pine Creek in northern Houston County, section 8, T104N, R4W. Whitford (1991) reports 2 -3 cricket frogs calling at this location. Pine Creek is a moderately sized stream with muddy banks that flows through a grazed pasture. A very large wetland is located approximately fifteen to twenty yards west of the stream.

Site 12. The site, a historic location from 1949, is located at the intersection of highways 7 and 26 in section 34, T104N, R4W, Houston County. The Root River runs along the north side of Hwy. 7, and a wetland is located on the southwest corner of the intersection.

Site 13. The Zumbro River, a historic location from 1966, is in sections 10, 11, and 13, T105N, R16W, Dodge County. The creek is slow moving and not very deep with some exposed muddy banks.

Site 14. The Root River at Stewartville, a historic location from 1939, is in section 34, T105N, R14W, Olmsted County. A medium sized, fast flowing river with some muddy banks, making the site moderately suitable for cricket frogs.

Southwest Minnesota

Site 15. Rock River at Edgerton, Sec. 28 T105N, R44W, Pipestone County. Site is located on the west side of Edgerton, on the north and south sides of highway 1. The north side of the road contains a campground and also a pond that is used for fishing. The river and pond were both checked and appeared suitable for cricket frogs. The south side of the road included the river and also another small pond about ten yards east of the river. This pond did not appear to have any fish present. This site appears quite suitable for cricket frogs. This site is a historical record from 1939.

Site 16. Chanarambie Creek on the east side of Edgerton, Sec. 27 T105N, R44W, Pipestone County. The creek looks to be somewhat suitable, but it cuts through pastures and had no backwater areas that we could find. Chanarambie Creek was recommended by John Schladweiler, the regional nongame specialist for southwest Minnesota.

Site 17. Poplar Creek, Sec. 32-33 T105N, R44W, Pipestone County. This site was located when traveling between sites. It appeared very suitable for cricket frogs, with some backwater areas and muddy banks.

Site 18. Blue Mounds State Park, Sec. 13-14 T103N, R45W, Rock County. Mound Creek at the northwest corner of the park was checked. The creek appeared moderately suitable, with some grassy banks, and some muddy backwater areas. This is a historic location from 1939.

Site 19. Gravel pits, Sec. 36 T103N, R45W, Sec. 1 T102N, R45W, Sec. 31 T103N, R44W, Rock County. Most of these pits are still operational and privately owned. We were unable to visually check along the pits but aural surveys were conducted. These are active pits, and therefore not very suitable for cricket frogs. These pits were recommended as potential sites by John Schladweiler of the Minnesota DNR.

Site 20. Rock River at Luverne, Sec. 11 T102N, R45W, Rock County. Site is in a park on the east side of Luverne. Site appears moderately suitable, with some shallow muddy banks and small backflow areas. This is a historic site from 1936.

Site 21. Game refuge south of Luverne on highway 75, Sec. 23 T102N, R45W, Rock County. Two large ponds with a lot of grass cover along the banks. Muddy banks seemed to appear only where fishing took place. This site may or may not have been a historical location. There is a record of a cricket frog collected south of Luverne on highway 75 in 1967.

Site 22. Ash Creek and Rock River, Sec. 13 & 24 T101N, R45W Rock County. Both of these water bodies appear suitable. The Rock River has somewhat steeper banks than Ash Creek, and both have some muddy banks and backwater areas. A historical site listed by the Natural Heritage database for *Acris crepitans* #21 was collected at a gravel pit with an outlet to Ash Creek. Although the gravel pit was not found, it shows that cricket frogs were found in or near Ash Creek.

Site 23. Kanaranzi Creek, west of Adrian, Sec.14-15 T102N, R43W, Nobles County. Three bridges cross the Kanaranzi and its tributaries west of Adrian. The eastern most tributary is a small wetland type with no open water, while the western and central bridges both have some open water. Kanaranzi Creek appeared suitable for cricket frogs. Mud banks, mud flats and backwater areas were all present along the stream. Kanaranzi Creek is a historic site for cricket frogs from 1936 and was recommended by John Schladweiler.

Southeast South Dakota

Site 24. Emmanuel Creek, 3 miles east of Running Water, Bon Homme County. This is a historic site from 1958,1960, and 1965. This site is a shallow slow moving stream with a lot of muddy banks, and some grass and tree lined banks. Overall habitat appears very suitable for cricket frogs.

Site 25. Owens Bay at Lake Andes National Wildlife Refuge, Charles Mix County. The refuge has a lot of cattails, and rip rap around the edge for erosion control. This is a historic site from an unknown date. The Bay and Lake Andes do not appear to be suitable habitat in its current form. Overabundance of cattails and the use of rip rap as an erosion control measure has eliminated any suitable habitat that may have once existed.

Site 26. Missouri River and Clay Creek south of Vermillion, Clay County. This is a historic site from 1958. The site along Clay Creek has muddy banks and some tree cover, but still appears to be suitable habitat.

Site 27. Lake Hanson, Hanson County. This is a historic location from 1959.

Site 28. Menno Lake, 3 miles northwest of Menno, Hutchinson County. This is a historic site from 1958.

Site 29. 11/2 miles south of Canton, Lincoln County. This is a historic site from 1963. The site has nice mud flats, some slow backwater areas, and appears to be relatively shallow. Overall habitat appears suitable for cricket frogs.

Site 30. 2 miles west of Hudson, Lincoln County. This is a historic location from 1966.

Site 31. .6 mile west of bridge over Keya Paha Railroad on highway 183, Tripp County. This is a historic location from 1967.

Site 32. Vermillion River 6 miles north and 11/2 miles east of Hurley, Turner County. This is a historic site from 1958.

Site 33. Swan Lake, Turner County. This is a historic site from 1958. This site has rock around nearly the entire lake for erosion control. During this study there was a dredging project at Swan Lake which disrupts the lake somewhat from its natural state. The habitat at the lake has been altered significantly since 1958 and is no longer suitable in its current state.

Site 34. Mud and McCook Lakes, Union County. These are historic sites from 1958, 1959, and 1968. Some cattails and dense vegetation along the banks. There also are some open mud flats and muddy banks with vegetation near them that would be suitable habitat for cricket frogs.

Site 35. Brule Creek at Union County State Park, Union County. This is a historic site from 1958. The creek is fairly large and fast moving. It has very limited mud flats and backwater pools and is somewhat suitable habitat.

Northern Iowa

Site 36. Gitchie Manitou State Park, Sec. 11 T100N, R49W, Lyon County. This is not a historic location. The park is bordered by the Big Sioux River on the west and a tributary of the Big Sioux runs to the north. With muddy banks, some vegetation, and some backwater areas on the Big Sioux, both of these appear suitable for cricket frogs.

Site 37. Rock River at Rock Rapids, Sec. 4 T99N, R45W, Lyon County. This is a historic site from 1940.

Site 38. Kanaranzi Creek, Sec. 22 and Sec. 20 T100N, R45W, Lyon County. This may or may not have been a historic record. This site has very muddy banks and is very meandering with some slow water areas. This is suitable habitat for cricket frogs.

Site 39. Rock River, Sec. 17 T100N, R45W, Lyon County. This is a historic location from the 1930's. This site appears to be suitable cricket frog habitat, with mud banks, some backwater areas, and is relatively slow moving.

Site 40. Lake Pahoja, Sec. 23 T99N, R48W, Lyon County. This is not a historic location. The lake has rip rap around most of the lake for erosion control and is used primarily as a recreation area. There are some siltation ponds in the watershed which may be better habitat than Lake Pahoja.

Site 41. Big Sioux River at Oak Grove State Park, Sec. 11 and 12 T95N, R48W, Sioux County. The muddy banks and backwater areas would be suitable habitat for cricket frogs. This is a historic location from 1967.

Site 42. Gravel pits, Sec. 16 T96N, R47W, Sioux County. This is a historic site from 1939. This gravel pit has been abandoned for long time. It is located less than a mile from the rock River. *Acris crepitans* were found again at this site on July 1, 1996.

Site 43. Lakewood Corners, Sec. 33 T99N, R45W, Lyon County. This is not a historic site.

Site 44. Little Rock River Conservation Area, Sec. 6 T98N, R43W, Lyon County. This is not a historic site.

Site 45. Rush Lake, Sec. 36 T100N, R40W, Osceola County. This is not a historic site.

Site 46. Iowa Lake, Sec. 9 T100N, R39W, Osceola County. This is not a historic site.

Site 47. Ocheyedon Pits, Sec. 23 T99N, R40W, Osceola County. This is not a historic site. The shores of the pits are very rocky and there is little to no vegetation present at the site.

Site 48. Ashton Pits, Sec. 11 T98N, R42W, Osceola County. This is not a historic site. There are not any mud banks present in this area. It does not appear to be suitable habitat for cricket frogs.

Site 49. Sec. 12 T94N, R40W, O'Brien County. This is not a historic site.

Site 50. Sec. 4 T95N, R39W, O'Brien County. This is not a historic site.

Site 51. Roadside ditch, Sec. 4 T93N, R48W, Plymouth County. This is a historic site from 1940. It remains in the same condition as described from the 1940 specimen. There is heavy vegetation around the entire waterbody. It is bordered on one side by a highway, and on the other three sides by row crops. This does not appear to be ideal habitat for the cricket frog. *Acris crepitans* were found again at this site on July 1, 1996.

Site 52. Silver Lake, Sec. 28 T100N, R38W, Dickinson County. This is a historic site from 1941.

Site 53. Pickerel Lake, Sec. 36 T94N, R35W, Clay County. This is a historic site from 1940.

Site 54. West Branch of the Des Moines River, Sec. 29 T98N, R33W, Emmet County. This is a historic site from 1943.

Site 55. Lost Island Marsh, Sec. 30 T97N, R34W, Palo Alto County. This is a historic site from the 1940's.

Site 56. Rush Lake, Sec 21 T94N, R34W, Palo Alto County. This is not a historic site.

Site 57. Devine Wildlife Area, Sec. 23 T94N, R29W, Kossuth County. This is not a historic site.

Site 58. East Fork of the Des Moines River, Sec 26 T94N, R29W, Kossuth County. This is a historic site from 1943.

Site 59. Rice Lake State Park, Sec. 24 T99N, R23W, Winnebago County. This is a historic site from 1943. There is some rock around the lake for erosion control. The lake appears somewhat suitable, but there are also backwater areas away from the lake that may be better habitat.

Site 60. Elk Creek Marsh, Sec. 5 T99N, R22W, Worth County. The exact historic location appears to now be a cornfield. Elk Creek Marsh is adjacent to the apparent historic site and was used instead.

Site 61. Beaver Dam Creek, Sec. 21 T94N, R20W, Cerro Gordo, County. This is a historic site from 1943. The creek is gently flowing with some exposed mud banks and also some larger mud flats. This site appears to be suitable habitat for cricket frogs.

Site 62. Little Cedar River, Sec. 19 T98N, R15W, Mitchell County. This is a historic site from 1942.

Site 63. Tributary of the Upper Iowa River, Sec. 2 T99N, R11W, Howard County. This is a historic site from 1940.

Site 64. Marsh on the east edge of Lawler, Sec. 3 T95N, R11W, Chickasaw County. This is a historic site from 1940.

Site 65. Wapsipinicon River Sec. 1 T95N, R14W, Chickasaw County. This is a historic location from 1940.

Site 66. Cardinal Marsh, Sec. 7 T98N, R10W, Winnishiek County. This is adjacent to a historic site from 1971.

Site 67. Upper Iowa River, Sec. 15 T100N, R4W, Winnishiek County. This is a historic location from 1951.

Site 68. Little Wapsipinicon River, Sec. 5 T91N, R10W, Fayette County. This is a historic site from 1934.

Site 69. Upper Iowa River, Sec. 15 T100N, R4W, Allamakee County. This is a historic site from 1939.

Site 70. Yellow River, Sec. 34 T96N, R3W, Allamakee County. This is a historic site from the 1940's. This site is near the mouth of the Yellow River at the Mississippi River. This area is heavily tree lined and very fast moving. It does not appear to be suitable habitat for cricket frogs.

Site 71. Stream in the woods, Sec. 21 T93N, R3W, Clayton County. This is a historic site from 1938.

Site 72. Miner's Creek at Guttenburg, Sec. 20 T92N, R2W, Clayton County. This is a historic site from the 1940's. This is a small fast moving creek with little to no backwater areas and many trees along the banks.

APPENDIX II

Results of Laboratory UV-B experiments

Table 3. Results of UV-B studies on a speceis of *Ambystoma* (sp)(either *A. tigrinum* or *A. texanum*) eggs.

Light treatment	Trial	End	Beg.	% Survival	Average Survival
Mylar	1	25	26	96.15%	96.97%
Mylar	2	7	7	100.00%	
Mylar		32	33		
Kodacel	1	19	28	67.86%	65.71%
Kodacel	2	4	7	57.14%	
Kodacel		23	35		
All light	1	4	27	14.81%	11.76%
All Light	2	0	7	0.00%	
All Light		4	34		

Table 4. Results of UV-B studies on *Acris crepitans* eggs.

Light treatment	Trial	End	Beg.	% Survival	Average Survival
Mylar	1	8	8	100.00%	87.96%
Mylar	2	11	11	100.00%	
Mylar	3	19	23	82.61%	
Mylar	4	37	39	94.87%	
Mylar	5	20	27	74.07%	
Mylar		95	108		90.99%
Kodacel	1	7	7	100.00%	
Kodacel	2	15	15	100.00%	
Kodacel	3	23	23	100.00%	
Kodacel	4	29	39	74.36%	
Kodacel	5	27	27	100.00%	
Kodacel		101	111		14.29%
All light	1	1	5	20.00%	
All light	2	8	18	44.44%	
All light	3	0	23	0.00%	
All light	4	0	39	0.00%	
All light	5	7	27	25.93%	
All light		16	112		

Table 5. Results of UV-B studies on *Bufo americanus* eggs.

Light treatment	Trial	End	Beg.	% Survival	Average Survival
Mylar	1	84	84	100.00%	99.57%
Mylar	2	79	80	98.75%	
Mylar	3	70	70	100.00%	
Mylar		233	234		
Kodacel	1	76	98	77.55%	92.41%
Kodacel	2	111	111	100.00%	
Kodacel	3	81	81	100.00%	
Kodacel		268	290		
All light	1	143	143	100.00%	97.99%
All light	2	70	76	92.11%	
All light	3	79	79	100.00%	
All light		292	298		

Table 6. Results of UV-B studies on *Pseudacris triseriata* eggs.

Light treatment	Trial	End	Beg.	% Survival	Average Survival
Mylar	1	70	80	87.50%	90.45%
Mylar	2	68	70	97.14%	
Mylar	3	13	13	100.00%	
Mylar	4	10	15	66.67%	
Mylar		161	178		
Kodacel	1	70	80	87.50%	84.27%
Kodacel	2	53	70	75.71%	
Kodacel	3	13	13	100.00%	
Kodacel	4	14	15	93.33%	
Kodacel		150	178		
All light	1	60	70	85.71%	56.55%
All light	2	20	70	28.57%	
All light	3	5	13	38.46%	
All light	4	10	15	66.67%	
All light		95	168		

Table 7. Results of UV-B studies on *Rana pipiens* eggs.

Light treatment	Trial	End	Beg.	% Survival	Average Survival
Mylar	1	41	56	73.21%	83.43%
Mylar	2	35	40	87.50%	
Mylar	3	21	25	84.00%	
Mylar	4	30	36	83.33%	
Mylar	5	24	24	100.00%	
Mylar		151	181		
Kodacel	1	44	56	78.57%	87.57%
Kodacel	2	35	35	100.00%	
Kodacel	3	19	25	76.00%	
Kodacel	4	40	45	88.89%	
Kodacel	5	24	24	100.00%	
Kodacel		162	185		
All light	1	4	27	14.81%	8.62%
All light	2	6	47	12.77%	
All light	3	1	26	3.85%	
All light	4	3	45	6.67%	
All light	5	1	29	3.45%	
All light		15	174		

Table 8. Results of UV-B studies on a species of *Hyla versicolor* complex eggs.

Light treatment	Trial	End	Beg.	% Survival	Average Survival
Mylar	1	5	31	16.13%	73.94%
Mylar	2	26	30	86.67%	
Mylar	3	39	41	95.12%	
Mylar	4	35	40	87.50%	
Mylar		105	142		
Kodacel	1	9	41	21.95%	69.78%
Kodacel	2	29	34	85.29%	
Kodacel	3	28	31	90.32%	
Kodacel	4	31	33	93.94%	
Kodacel		97	139		
All light	1	9	39	23.08%	19.42%
All light	2	7	34	20.59%	
All light	3	6	33	18.18%	
All light	4	5	33	15.15%	
All light		27	139		